The Postnatal Growth of the Body, Systems and Organs of the Single Comb White Leghorn Chicken.

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I. Introduction.

The problem of growth has been studied in many forms of life and from various points of view, and yet many of its fundamental aspects are still unknown or imperfectly understood. A large amount of data has been accumulated concerning the growth of mammals, especially in man and the albino rat, but comparatively little upon lower forms. In birds, there have been a few studies upon the growth in body weight of the domestic fowl, but little upon the growth of the individual organs and systems.

A systematic study of growth on this animal therefore seemed desirable for various reasons. The domestic fowl (Gallus domesticus) is easily obtained for experimental investigation. It is omnivoram, and has a relatively short period of growth. Moreover, its economic value should add to the importance of a better knowledge of its anatomy and of the growth changes which occur in the various organs and systems of this animal during its development.

This study was undertaken upon the suggestion of Professor C. M. Jackson, and to him and to Professor R. E. Scammon I wish to express my deepest gratitude for their comnsel and advice throughout the course of this investigation. The writer is also greatly indebted to Professors A. C. Smith and C. P. Fitch, for the generous provision of material and facilities for this investigation. The study was undertaken in the department of Anatomy, in cooperation with the division of Poultry Husbandry of the University of Minnesota.

II. Literature.

As previously mentioned, the literature upon the growth of the domestic fowl is very limited in amount. It consists chiefly in a few reports giving the average weight of a number of birds at certain stages of their growth, and usually covering only brief periods.

Petrov ('86) studied the effects of hunger on the body weight in fowls, including a few observations upon a group of normal controls at various ages. He does not state the breed used and his data are therefore of little value for comparison.

Houssay ('02) studied the growth of a number of chickens and plotted the growth curves. Stefanowska ('05) plotted separate growth curves of growth in body weight for the males and females of a group of chickens.

Minot ('07) followed the growth of two male and eight female chickens, making weighings daily at first and later less frequently up to 190 days; then three weighings between 335 to 350 days of age. He found an initial decrease in weight after hatching similar to the postnatal decrease in mammals.

Lee ('11) made a very careful study of the fattening of poultry. The time during which the maximum gain occurs, the amount of feed required, and the average gain for several different breeds were determined.

Mitchell and Grindley ('13) made a study of the same problem for poultry as well as for some of the larger farm animals.

Philips ('16) published the results of growth experiments during four years upon several thousand Single Comb White Leghorn chicks in the Indiana Experiment Station. The sexes were weighed together until the young cockerels could be picked out, and from this time on to the end of the twenty-fourth week only the pullets were weighed.

Card and Kirkpatrick ('18) published their growth studies which had been carried on during the three preceding seasons. They used Single Comb White Leghorns and Rhode Island Reds from the regular stock of the Connecticut Experiment Station at Storrs, Conn. The chicks were carefully weighed in lots, once per week, and the average weight per chick determined for twenty-four weeks. The cockerels were removed at the end of the eighth week and after this only the pullets were weighed.

Buckner, Wilkins and Kastle ('18) studied the growth in body weight of two lots of Single Comb White Leghorn chickens at the Kentucky Experiment Station. One group was incubator-hatched and raised in a brooder; the other was hatched and reared by hens. They started with 60 chicks in each lot. The chickens were weighed individually each week and the average for each sex was determined for a period of 28 weeks.

When we turn to the growth of the systems or organs of the domestic fowl, we find still less in the literature.

Welcker and Brandt ('03) give the body weight and weights of the organs and systems in two male domestic fowls. There are also some weights given for the organs of the chick on the 9th, 10th, 11th, 13th, 17th, 20th and 21st days of incubation, one "Junges Hühnchen vom Markte" and a hen. The breeds are not given and of course the number of cases is not adequate to determine the average weights. They give similar data for nine other species of birds, including two pigeons and two domestic geese.

Stieve ('18) studied the development of the ovary in the hen, but has made no observations upon the other organs.

Some statements in the literature concerning the persistence of the yolk-sac will be given later in connection with the discussion of the digestive system.

III. Material and Methods.

The chickens used were Single Comb White Leghorns, which were provided by the division of Poultry Husbandry. They were hatched in four groups. Group I was hatched May 29, 1920, but the weighings were not begun until June 26, at which time there were 95 chicks four weeks old. On July 13, this lot was transferred to two coops with free range, and 32 culls were removed. On October 27, 1920, they were moved into winter quarters and the sexes were separated. Group II was hatched July 8, 1920, and included 21 chicks. Group III, hatched July 17, 1920, consisted of 36 chicks. Groups II and III were kept in the brooder house, but during the latter part of the summer and fall they were allowed to run in a large, grassy, fenced lot adjacent to the small runs. The last chick in group II was autopsied Nov. 13, 1920. Groups I and III were in part carried through to the end of the experiment, and the remaining chickens returned to the Poultry Department. The males and females in Group III were not separated. Group IV included 18 chicks, hatched Aug. 11, 1920. The last one of this group was autopsied Nov. 15, 1920.

All of the chicks were hatched in the incubators at the poultry plant and, with the exception of group IV, they were all put into the brooder house as soon as all of the chicks in the incubator were dry. This was usually about twenty-four hours after the first chick had hatched. The age of the chickens was counted from the time of removal from the incubator, so there is a variation of a maximum of about twenty-four hours in their ages. Group IV was given to an old hen, confined in a coop, but allowing free range for the chicks. Later the hen and chicks were put in a section of the brooder house with access to a grassy run.

From the beginning, all were fed "Chick Starter", a commercially prepared mixture of seeds, and a commercially prepared mash, "Peep o' Day". After June 21, 1920, all the chicks were provided with hoppers filled with a mash composed of equal parts (by weight) of bran, hominy, middlings, ground oats and beef scraps. As soon as old enough, they were given a mixture of cracked grains (corn, oats, etc.) and later whole grain. The last three groups were given milk to drink from the beginning, and Group I after June 26. After Nov. 27, 1920, the remaining chickens were given the regular "laying mash", hopper fed. This mash as mixed by the Poultry Division consists of the following:

6 lbs. corn meal
4 " ground oats
4 " middlings
2 " bran
2 " alfalfa meal
7 " beef scraps
1/4 " charcoal
1 per cent common salt
3 " " bone meal

With this mash was given the usual allowance of grain. Throughout the experiment they were fed by the Poultry Division, so that they might have the usual care and diet.

Complete autopsies were made on 100 normal chickens, 50 from group I, 15 from each of groups II and III, and 14 from group IV. In addition th these 94 normal chicks at various stages, 6 older normal chickens (adults) were likewise autopsied for comparison. A series of 15 malnourished chickens (not included in the present study) was also autopsied.

The following table will briefly summarize the specimens used.

Total number of young chicks at beginning	174
Autopsied normal at various ages, up to adult ...	94
Autopsied for inanition series	15
Returned to Poultry Division at end of experiment	13
Culls (excluded as abnormal)	32
Lost (died or escaped)	20
Total	174
Autopsied from normal adult stock not included in gross weight studies	6
Grand total..	180

The number of birds used is not sufficient to establish final conclusions on many points, but the results will at least indicate the general trend of the growth changes which occur in the Single Comb White Leghorn from time of hatching to maturity. These results will serve as a basis for further and more detailed study of various phases of the problem, such as the variations due to nutrition and other environmental factors, variations in different breeds of fowls, etc.

Weighings.--The chickens in group I were weighed once a week from June 26, 1920, to March 4, 1921. The other three groups were weighed every day from day of hatching (or when they were removed from the incubator) until the first of October; then only three times per week until December 3, and once per week thereafter, until killed and autopsied. The weighings were always made in the morning before the chickens were fed or allowed the freedom of the yard or range. They were weighed on a pair of spring milk-scales, sensitive to a hundredth of a pound. The entire group, or as many as possible, were weighed at a time and the average weight per chick (in grams) was determined. The three groups which were kept in the brooder house and weighed every morning became very tame, and so were not frightened by the necessary handling. During the winter those in group I were much less wild than when on the range.

Autopsies.—In selecting individuals for autopsy those which were most nearly in accord with the weights as given by Card and Kirkpatrick ('18) at corresponding ages were selected at various periods. This makes the average weight of the autopsied chickens higher than the average weight of the entire lot at the corresponding points (see Chart V).

The technique of the autopsy was as follows: The chickens were chloroformed and then weighed. The feathers were pulled off and the chicken again weighed, the difference giving the weight of the feathers. The measurements of the chick were made after the removal of the feathers and the second weighing. The bird was laid right side down on a piece of paper, the neck gently straightened and the length from tip of bill to anus marked on the paper. The distance from back to toe was measured in a similar manner. The other measurements were made with a pair of dividers. They include the following: length of leg from tip of toe to greater trochanter; length of wing, from tip to proximal end of humerus; length of head; and the dorsoventral, and the transverse diameters of the thorax, just behind the anterior end of the sternal crest.

The head was then cut off, the incision being made close to the base of the skull and through the spinal cord as it passes through the foramen magnum. The esophagus and trachea were severed just below the pharynx.

The blood was allowed to drain from the severed vessels and was not measured. The blood, larger masses of fat, mesenteries and larger vessels and nerves were not weighed separately. The integument was next removed. This includes the skin, with scaly skin from legs and feet, horny beak and claws; also some dermal fat which could not easily be removed, and the dermal muscles, especially in the neck and lateral thoracic regions. The uropygial glands were removed with the skin. The wattles and ear lobes were not weighed separately at first, and so are included in the integument of the smaller chicks. They were not of sufficient size to modify the results, for as soon as it was possible to separate them they were weighed separately.

So far as possible, all fat and mesenteries were removed from the viscera, and they and the parts of the body were immediately put in a moist chamber until weighed. The organs were weighed in closed containers on a chemical balance sensitive to a tenth of a milligram. The body, after removal of all viscera, was cleared of all excess fat, mesenteries, etc., and weighed (in the case of the larger chickens) on a laboratory balance sensitive to one-tenth of a gram.

The digestive tube includes all of the canal from beginning of esophagus to the termination of the intestine in the cloaca. The cloaca was not included. The entire digestive tube, together with contents, was first weighed; then the stomach and gizzard were cut out, opened and each weighed after removal of contents. The crop was opened and contents removed. Next by gentle pressure the contents of esophagus and intestines were forced out. Then esophagus, crop and intestines were weighed together. From these weighings the weight of the entire empty canal and the 'tare' (weight of contents) were computed.

The muscles were then removed by careful dissection, and the ligamentous skeleton, with contained central nervous system, was weighed. Then the brain and spinal cord were removed and weighed.

The data were recorded upon individual record cards and finally plotted in the form of the various field graphs and curves shown in charts I to XXXV.

The curves shown in chart V are point to point curves made by connecting the average body weight of the chickens for each week. In the construction of the other curves the numerical averages of the gross body weight or the absolute weight of the organ were determined in general for each increase of 200 grams in gross body weight, and these average points were plotted on the chart. Then by means of French curves the growth curves were drawn in to fit the group averages as closely as possible. The net body weight (gross body weight minus the weight of the contents of the digestive tube) was used in determining the percentage weights. Crelle's Rechentafeln was used in computing the data.

IV. Growth of the Body and Parts.

a. Growth in Body Weight.

Growth in body weight is but an incidental and subordinate part of my problem. The increase in the gross body weight of the White Leghorn chick has been worked out thoroughly and for a large number of chicks by Philips ('16), Card and Kirkpatrick ('18) and Buckner et al ('18). The weighing of the chicks for the present experiment was undertaken chiefly to serve as a check upon the individuals selected x for the autopsies. It will be shown, however, that the various groups in the present experiment give some information as to the relative effects of certain kinds of food and care upon growth of the chickens. A reduction of 23 days in the period between hatching and egg production (as in group III compared to group I) is a matter of practical interest. The importance of the time of hatching is also indicated by the slow growth of group IV, a late hatched group.

Charts I, II, III and IV show the average growth curves for the chickens in each group. Chart V shows the average weight per chick for all groups, plotted on age in days. The upper line after the 56th day represents the average weight of the males, and the lower line,the females. The sexes were not weighed separately until the 56th day. The weights of the autopsied chicks are indicated by large dots for the males and a small dot within a circle for the females. The three males placed in the right margin were older cockerels, probably from 4 to 6 weeks older than mine, and the three females were hens about two years old. The exact ages of these six specimens were not known, but they were studied to give some idea of the changes after 300 days of age or in chickens of mature weight.

Groups II and IV were weighed for only a short time, and so the growth curves of charts II and IV show only the first and the beginning of the second phase of the typical growth curve. Charts I, III and V show the three phases of the postnatal growth of the entire chicken, which are as follows: (1) a period of relatively slow increase in weight; then (2) a period of rapid growth which (3) decreases after the time of sexual maturity is reached, with the resulting flattening (horizontal tendency) of the curve. The irregularities in the terminal portion of the curve (especially noticeable in chart V) are due in part to the much smaller number of specimens weighed in the later periods. Any individual fluctuation consequently would modify the curve to a much greater degree.

There is a slight flattening of the curve for the females in charts I and III, at about 150 days for group I and 130 days for group III, or about 40 days before egg laying begins. This would suggest a prepubertial pause in growth, which does not occur in other ~~domestica~~ domestic animals. The significance of this pause is questionable.

The growth data as given by the previous investigators, when plotted on the same scale as the present charts are of interest for comparison. The data of Philips ('16) and Card and Kirkpatrick ('18) include only the weights of the females after it is possible to separate the males. Buckner et al ('18) give the data for males and females separately. For comparison, I have grouped their data for the two sexes together up to the ninth week. When the growth curves are compared it is seen that the average weight of the chickens used in the present work falls below the other three at first. It never runs as high as the curve constructed from the data of Card and Kirkpatrick. They carried their weighings only through the 24th week, but at this time their chickens (females only) averaged 1489.12 grams while the Minnesota chickens averaged 1298.44 grams. The chickens reported by Philips, ('16) from the Indiana Experiment Station were heavier than mine up th the thirteenth week, when both groups averaged about 650 grams. From this time on they were a very little lighter than mine. The Indiana experiment was continued for only 24 weeks, at which time their chickens averaged 1248.50 grams, while mine averaged 1298.44 grams.

The curve constructed from the data on the growth of the chickens reported by Buckner et al ('18) from the Kentucky Experiment Station is more irregular than any of the others. It also runs higher than the present series up to between the 13th and 14th weeks, and then it falls below. At the end of the 28 weeks the pullets from the Kentucky Station averaged 1447.5 grams, for the hen-hatched and reared, and 1120.4 grams for the artificially hatched and reared pullets, as compared with 1539.06 grams for the artificially raised Minnesota pullets. The Minnesota cockerels likewise average lighter than both the artificially and the hen-raised Kentucky cockerels up to the 19th and 20th weeks. After this time mine were heavier than their artificially raised cockerels and slightly heavier than their hen-raised males. At the end of the 28th week, when their experiment was concluded, my cockerels averaged 1802.38 grams, the hen-hatched and hen-reared cockerels from the Kentucky Station averaged 1748.1 grams and the artificially hatched and reared averaged 1594.6 grams.

At hatching, the average weight for my series is 36.59 grams; for the Connecticut chicks, 36.70 grams; and for the Kentucky series 41.5 grams for the hen-hatched and 41.6 grams for the artificially hatched.

There is a difference in the growth of the chicks in my four groups. At the time of removal from the incubator their average weights were: group II, 34.47 grams; group III, 36.29 grams; and group IV, 19.01 grams. Group I was not weighed until the chicks were 28 days old, and at that time the respective weights were: group I, 87.8 grams; group II, 136.1 grams; group III, 129.3 grams, and group IV, 113.4 grams.

Group IV, it should be remembered, was hatched late in the summer, and although hen-reared, which has been shown to be better than artificial brooding, yet this did not compensate for the unfavorable weather conditions. Group I, up to this time (28 days) had been given no milk, and dry mash had not been kept continually before them. When milk and a constant supply of mash was supplied, group I began to improve. The greater freedom of the range was given to this group alone; yet they lagged behind the other groups, and the first egg was laid by this group at 189 days, and by group III at 166 days. Thus group III began laying at an age of 23 days younger than group I.

Chart VI gives only the first 25 days of the curve of chart V, plotted on a larger scale. It shows the characteristic postnatal decrease in weight, which is found in so many animals and which Minot ('07) found to persist in the chick until 'by the fourth or fifth day they appear to entirely recover'. It will be seen that the average weight of the chicks from groups II, III and IV is below the initial weight on the 1st, 2nd and 3rd days, with the minimum on the 3rd day. The initial weight is that observed when they were taken from the incubator. Not until the fourth day is the average weight greater than the initial weight. This decrease in weight takes place although the chicks begin picking up sand as soon as placed in the brooder. In the chick autopsied after one day the gizzard was filled with fine sand, and the digestive tract contents formed 4.0 per cent of the net body weight. In the chick at two days this tare formed 12.1 per cent, and at three days it had risen to 15.8 per cent of the net body weight.

The gross weights of the 100 autopsied chickens shown in chart V are higher than the average live weights for the groups from which they came. During the earlier part of the work, individuals conforming to the average weight as given by Card and Kirkpatrick ('18) for corresponding ages were selected, and this naturally raises the average for the autopsied chickens.

The drop in the average weights of the pullets after 200 days is similarly due to the removal of the larger pullets earlier in the experiment, and is not the result of a decrease in weight of the individual pullets. The weights of the six older birds indicate a continued slow average increase in the period after the weighings were stopped. This increase is due very largely to an increase in adipose tissue, although some organs also continue to grow, as will be shown later.

From the foregoing data it may be concluded that the chicks show a postnatal loss in body weight which is not recovered until the fourth day. The curve of postnatal growth in weight shows three general phases: first a period of slow growth, then a period of rapid growth, followed by a slow increase which may continue for some time. There is possibly a slight prepubertal retardation and rise, but this is doubtful. After 70 days the cockerels become distinctly heavier than the pullets of corresponding age.

b. Growth in Linear Measurements.

1. Body Length.—The growth in length of the chick from the tip of the beak to the cloacal orifice is shown in chart VII. A comparison of this chart and chart V shows that nearly the maximum length is reached at a little past 110 days for the pullets, or when they reach about 55 per cent of the mature weight; and about 35 days later for the cockerels, or when they reach about 75 per cent of their mature weight. The greater increase in body weight in the pullets after the completion of ossification is in part due to the additional weight of the reproductive tract and the greater amount of fat. Still both of these factors will not account for all of the difference. We must therefore conclude that the maximum length, or the fusion of epiphyses and diaphyses, occurs earlier in the pullet, not only in relation to age but also in relation to the attainment of the total body weight.

2. <u>Extremities</u>.--Chart VIII shows the increase in length of the leg in the upper curves and the wing in the lower curves. The back-toe measurements were also plotted; but the curve corresponded closely to that for the leg (except that it was about 1-1/2 cm. greater) and it has therefore been omitted from the charts.

The growth in length of the leg corresponds closely with that for the body, the completion of growth (curves becoming nearly horizontal) being at nearly the same time for each. The males become taller, however, and continue to increase in height after the females have attained their maximum height.

The lower curve in chart VIII shows for the wing length a less marked sex-difference. In this case the time of cessation of growth in length is also less definitely marked. Possibly the maximum point of the curves comes a little earlier than is found in the curve for the leg-length.

3. <u>Thorax</u>.--On chart IX, the two diameters of the thorax are plotted against age. The dorsoventral diameter was taken just back of the anterior end of the crest of the sternum and the transverse diameter was always taken in the same plane. Both of these diameters show a longer period of increase than do the preceding linear measurements. This may be explained by the fact that these measurements are not purely skeletal measurements. As can be seen by a comparison of the two sets of curves, the transverse diameter increases for a longer time than does the dorsoventral diameter. This measurement is affected more by the deposit of fat, a large mass of subdermal fat being found on either side of the breast in the fat chickens. Another factor which influences these measurements is the possible increase in the size of the thoracic cavity and the dilation of the bony thorax. The six older chickens differ from the others

more in these two measurements than they do for the two preceding measurements shown in charts VII and VIII.

The thoracic index $\left(\frac{\text{dorsoventral diameter X 100}}{\text{transverse diameter}}\right)$ was determined for the chickens. Throughout the entire series, and including the six older birds, there appears no significant change and no sex-difference. The index averages about 175.

Had these two diameters of the body been made in the abdominal region there would have been apparent a much more marked sex-difference; for in the latter part of the period during which the birds were studied there is a marked difference in the shape of the body in the male and female. In the male the maximum depth or dorsoventral diameter is but a centimeter or two caudad to the point used in measuring this diameter. In the pullets, however, the anterior end of the body had the smaller dorsoventral diameter. In other words the posterior region of the female body cavity becomes distended with the larger reproductive tract, and the greater accumulation of fat in this region, tending to push downwards the ventral body wall. This produces the ventral sagging of the abdominal wall, which is characteristic of a laying hen.

4. Head-Length.--Chart X shows the increase in length of the head. It resembles the wing length more closely than the leg-length. There is less sex-difference than would be expected from the weights. As will be shown later, the male comb is far larger and the weight of the head in the older male birds is consequently greater than the weight of the head in the females. A study of charts X and XI will suggest that the sex-difference so evident in the head weight is due very largely to the greater weight of the male comb and wattles. The linear measurements when plotted on age all show a continuous convexity superiorly although the curves show different rate of growth and rates

differing at different ages of the chicks. The linear measurements employed all show an earlier maximum than do the curves of gross body weight (chart V).

c. <u>Head-Weight.</u>

The increase in absolute weight of the head plotted on gross body weight is shown in chart XI. The cases in which the body weight is over 2200 grams are the adult specimens. They are not included in the curve, although the individual head weights are indicated on the chart. From 400 grams gross body weight or 55 days of age there is a sex difference in head weight, due in large part as suggested above to the greater development of the comb and wattles in the males. The percentage weight of the head shows no initial rise but drops rapidly at first and later shows a sex-difference. Jackson and Lowrey ('12) found that in the postnatal growth of the rat, the head at first increases more rapidly than the rest of the body and that there is no sex-difference. The head is relatively much lighter in the chicken, for its maximum percentage weight in the chicken is a little less than half that for the rat. In the adult rat the head forms about 9 per cent of the body; while for the chicken it is only about 4 per cent in the male and between 2 and 3 per cent for the female.

V. Growth of the Systems and Organs.

a. Integument.

1. Skin.--Chart XII shows the weight of the integument excluding feathers, comb and wattles, plotted on gross body weight. From this chart it is clearly evident that the growth of the skin is in direct proportion to the total increase in body weight, and that there is no appreciable sex-difference. The percentage weights of the skin show no marked changes, forming about 8 per cent of the net body weight. This is less than the figures given by Welcker and Brandt ('03). They give 18.86 per cent for skin and subdermal fat for the domestic fowl and from 12.57 to 18.07 per cent for the skin only of the other species of birds investigated. These percentage weights doubtless include the feathers, however, which would make them more nearly comparable with mine. The percentage weight of the skin for the various animals as given by Welcker and Brandt show a wide range and in most cases greater than the values found in my chickens (without feathers). According to Wiedersheim, the skin of birds is relatively thin; moreover, in removing the feathers, the shaft is not left in the skin to be weighed with the integument.

2. Feathers.--The growth of the feathers (chart XIII) follows a course entirely different from that of any of the preceding curves and resembles the growth of the thymus (see chart XXVI). In the Single Comb White Leghorns, the wing feathers begin to appear very early and the rest of the plumage is developed earlier than in some other breeds. The weight of the feathers increases more rapidly than the body weight, increasing from a little over 4.5 per cent to nearly 10 per cent of the net body weight, and then decreasing again to about 6 per cent. The absolute weight of the feathers increases without any sex-difference until the body weight reaches 1400 grams;

then the curve for the females begins to decline. The curve for the male plumage increases during an increase in body weight of about 200 grams, and then it too decreases. The sex-plumage, the sickle-feathers, saddle-feathers and the long feathers on the neck are the last to develop, and the growth of these probably carries the curve for the male plumage on to a higher level than that reached by the female plumage.

The averages for the plumage of the adult birds are not included in the curve although the cases are shown on the chart. The same rise, followed by a decrease in the female and later in the male plumage, is also observed when the absolute weights are plotted against age.

This rise and fall in both the relative and absolute weights, plotted against both the gross body weight and against time, are correlated with changes in the structure of the feathers. Until the feather is completely developed, the shaft contains a large amount of vascular tissue, but later the vascular tissue in the shaft atrophies and dries out. This results in a marked decrease in weight of the plumage. The female plumage is completed before that of the male, thus resembling the growth of the body and the ossification of the skeleton, as already shown.

3. Comb and Wattles.--Chart XIV shows the absolute weights of the comb and wattles combined, and the weight of the two ear lobes for the older chickens. All are plotted against the gross body weight. In the very young chicks the wattles were so small that they could not be separated from the integument over the mandible. Just as soon as they could be distinguished they were removed and weighed with the comb. No attempt has been made to draw a curve for these weights because they are so variable. When plotted against age or body weight the comb and wattles of the male birds are more irregular in their growth than are those of the females.

The ear lobes were not weighed in all cases and hence are not shown for all the chickens. Their increase in weight appears to be more regular than that of the comb and wattles.

b. Muscular System.

The absolute weight of the (skeletal) musculature plotted against gross body weight is shown in chart XV. The muscles and integument form nearly straight lines when thus plotted, as shown in charts XII and XV. The muscles were also plotted on age, and the resulting curve resembled the curve of gross body weight (chart V). Chart XV shows possibly a very slight sex-difference in the heavier chickens. The percentage weights of the muscles show an increase from about 21 or 22 per cent of the net body weight at hatching to a little over 50 per cent for the larger chickens. The musculature of the three older cockerels averages about 50 per cent while the three hens average only about 43 per cent. There is a similar difference in the older chickens in my series, the muscles of the males forming a larger percentage of the net body-weight than do those of the females. It is popularly supposed that there is relatively more 'meat' (muscle) in a hen than in a rooster, but the present data shows that this is incorrect.

The musculature in the chicken at first increases in weight more rapidly than the rest of the body and later forms about 50 per cent of the net body weight, with no marked sex-difference. There is in the chicken no postnatal decrease in percentage weight of muscle, as described by Jackson and Lowrey ('12) for the rat.

The relative weight of the muscular system seems to vary greatly in different species. According to Welcker and Brandt ('03) it varies from about 19 per cent in the tortoise to nearly 59 per cent in the perch. Their average for the domestic fowl was 54.5 per cent.

Jackson and Lowrey ('12) have pointed out that the percentage weight of the muscles does not vary in proportion to the size of the animal. There seems to be some evidence to indicate that within a group of phyla of animals, the activity, or the ability to perform powerful or rapid movements, is correlated with the relative weight of the musculature in the animal.

c. Skeletal System.

Chart XVI shows the absolute weights of the moist ligamentous skeleton, plotted against gross body weight. It shows no sex-difference until a body weight of 1200 grams is reached. Unfortunately there are no male skeletons at body weights between 950 and 1190 grams, but there is probably no marked change, since the curve for the males continues in almost a straight line after this point.

At about 1000 grams of gross body weight there comes a marked change in the curve for the female skeletons; it continues to increase but not nearly so rapidly as before this time. The curve for the male skeleton continues at about the same rate until 1600 grams in body weight is reached. From this point on they too show a relatively slower skeletal growth.

The cases shown on the chart above 2200 grams in gross body weight are the six older chickens. It is seen that these fit into the curve for the younger chickens, indicating that there is no radical change in the skeletal weight after about 300 days.

When the weights of the moist ligamentous skeleton are plotted against age there is even a more evident sex-difference, the curves of male and female skeleton separating at about 120 days of age.

The relative weight of the skeleton shows at first a very slight increase, attaining a maximum average of about 16 per cent and then decreasing to about 11 per cent for the males and about 9 per cent for the females. The greater percentage weight of the moist ligamentous skeleton in the cockerels cannot be accounted for entirely by the smaller proportion of fat or of reproductive tract in the male. It must be due to other difference in the structure of the birds. The cockerel is characteristically longer-legged than the pullet. Moreover, the shape of the body is different (as mentioned previously), the cockerels having a larger anterior part of the body, which contains more bony skeleton; while the pullets have a relatively larger posterior part of the body which is not so well supplied with skeleton.

The sex-difference in ligamentous skeleton of the chicken is also apparent in the relative (percentage) weight above 1200 grams in body weight. The figures given by Jackson and Lowrey ('12) for the relative skeletal weight in the rat are slightly higher, and show no sex-difference. Welcker and Brandt ('03) give 11.69 per cent average for the two male chickens.

d. Digestive System.

1. Digestive tube.—Chart XVII shows the growth in weight of the entire digestive tube, without contents, plotted against the gross body weight. It is a smooth curve, rising more rapidly at first and then gradually flattening out horizontally. There is no apparent sex-difference. The weights of the digestive tube when plotted on age form a curve strikingly like chart XVII, except that the first part of the curve is concave on its upper side and there is a slight difference in the curves for the males and females. In this case (as also for other organs) the curve for the male digestive tube is higher, corresponding to the greater body weight of the males.

The curve of relative (percentage) weight shows a very short initial rise, followed by a slow decrease which tends to fall a trifle lower than the initial relative weight of the tube. The percentage weights of the empty tube in the nine chicks ranging in age from day of hatching to 8 days old are as follows, in order of age: 8, 8.2, 13.6, 12.4, 14, 13.9, 18.5 (for the 6th day, the highest of all) 15 and 14.

Welcker and Brandt ('03) give 5.02 per cent as the average for the canal in their two male chickens (adult). This is very close to my older cockerels and but slightly higher than that for the hens. Jackson ('13) finds about the same percentage values for the adult rat, (esophagus not included), but that it increases from an average of about 2.4 per cent in the newborn to a maximum of about 8 per cent at six weeks of age. Thus the maximum relative weight of the digestive tube is attained much earlier in the chick and at this time it forms twice the relative weight of the tube in the rat. The greater weight of the tract in the chick at the beginning may be correlated with the difference in diet. In addition the chicken has the heavy-walled gizzard which frequently equals the weight of the intestines, crop and esophagus together.

2. Stomach.--Chart XVIII shows the growth in the absolute weight of the stomach plotted against gross body weight. The cases appear more irregularly scattered than in the charts of the other parts of the digestive tube, due perhaps to three things: (1) the scale of ordinater is larger; (2) the separation of the stomach from the rest of the digestive tube was rather difficult, for there is no sharp line of separation between it and the esophagus; (3) the stomach may vary in size more than the gizzard.

3. Gizzard.--Chart XIX shows the absolute weights of the gizzard, separately plotted against gross body weight. The relations are discussed later.

4. <u>Intestines</u>.--Chart XX shows the weights of the intestines (also including crop and esophagus) plotted against the gross body weight. The large paired caeca are also included with the weights of the intestine. A comparison of charts XIX and XX showsthat while the intestines and gizzard grow at very nearly the same rate, yet the gizzard lags behind the intestines throughout the middle part of the curve. This would indicate that the intestines get their complete growth a little earlier than the gizzard.

The three regions into which the digestive tube was divided grow apparently at about the same rate. A comparison of the charts (XVIII, XIX and XX) will show a marked similarity.

<u>Contents of digestive tube</u>.--In connective with the digestive tube may be mentioned the contents found therein. The stomach never contained much food, usually none; while all of the other parts of the canal (from crop onward) were usually more or less filled. In the stomach was always found a characteristic whitish mucus, lining the walls, which were thrown into longitudinal folds.

The use of gross or net body weights for abscissae and for calculation of percentage weights raised the question of the amount of 'tare' or contents of the digestive tube. For abscissae, it seemed best to use the gross weights, for these are more easily determined and more generally useful for reference; but for calculating percentage weights, the net body weight was used. It was thought that a corrective factor could make possible the conversion of gross into net weight, or <u>vice versa</u>. The absolute and the percentage weights of the tare were therefore plotted on age, but there appeared a surprising variability in both cases. As might be expected the increase in contents is very rapid at first. For the newly hatched and succeeding three days the absolute weights are: 0.7, 1.4, 3.7, and 6.0 grams. Up to a little after the 100th day the variation in absolute weight of the 'tare' is not great, but after the 100th day the range is from 30.9 grams to 160.9 grams. The relative weights, for the first 6 days, following the dat of hatching, are: 2.3, 3.95, 12.1, 15.8, 14.3, 18.2 and 19.3 per cent, reaching the maximum found in any specimen. While the cases are very irregularly arranged, their average slowly falls after the 6th day to about 4.5 per cent of 'tare' for the adults. The use of this number as a means of changing from gross to net body weight would give only approximate results, however, for the variation is very great.

A part of the 'tare in the fowl is the gravel in the gizzard. In a majority of the older chickens, some grit or small stones appeared in the large intestine. Whey they should be more abundant in this part of the intestine is not easy to say. The presence of grit in the posterior part of the intestine was not observed in the younger chicks. Fine sand was found in quantity in the gizzard of the oné day old chick, or before there was any food present.

Jackson and Lowrey ('12) find that the intestinal contents for the albino rat during postnatal life do not average more than 5 per cent of the body, excepting at 6 weeks, when the average was about 8 per cent.

5. Yolk-sac.--At this point is might be well to give the findings concerning the postnatal persistence of the yolk-sac. As is well known, the yolk-sac is enclosed by the abdominal wall just before hatching, and on the young chick just after hatching, the resulting scar can readily be seen.

Aristotle long ago observed the yolk-sac ten days after hatching and William Harvey found it in a chick 13 days old. H. Virchow ('91) found yolk-sac weighing an average of 5.34 grams just after hatching, but reduced to about 0.05 gram on the 6th day. Kaupp('16) reported an average weight of 8.5 grams for the yolk-sac in ten newly hatched Single Comb White Leghorn chicks. At 43 hours he finds it reduced to 5 grams and still present at 120 hours although the weight is not given.

In my series the yolk-sac was found in every chick, with one exception (31st day) up to and including the 38th day. From the 38th to 108th days, inclusive, it was present 15 times and not found in 12 chicks. After the age of 108 days, the yolk-sac was found in eight chickens, 4 males and 4 females, the older being a cockerel 237 days old. It was exceedingly variable in weight. For example, the first yolk-sac weighed 5.05 grams; at one day, 7.56 grams (the heaviest found). In the chick at 2 days it weighed but 1.4 gram~~s~~ and at 12 days, 6.01 grams.

The following table will give the data for the last six cases found.

Sex	Age in days	Gross body weight grams	Yolk-sac weight grams	Percentage of net body weight
m.	151	1633.2	0.079	0.0050
f.	167	1324.7	0.058	0.0046
m.	172	1820.9	0.822	0.048
f.	181	1363.8	*____	____
f.	202	1707.3	0.033	0.0020
m.	237	2023.5	0.858	0.0459

*Yolk-sac was 2 mm. in diameter, but was not weighed in this case.

In the cases observed the yolk-sac was found soft and either attached or more or less imbedded in the abdominal wall (as was the last one), or it seemed to have broken free from its attachments and formed a hard spherical structure filled with a more or less chalky mass. It was found in various positions in the abdominal cavity, with very slight or no attachments.

Meckel's diverticulum, at the primitive attachment of the yolk-stalk, persists as a small tubular outgrowth from the free side of the intestine. It was 6 mm. in length in the 230 day chick, which was about the average. There seems to be a tendency for this to shorten very slightly with age, but even in the hens two years old it was present as a small diverticulum several mm. in length and always with a lumen open widely into the intestine.

6. <u>Liver</u>.--The growth in weight of the liver and gall bladder (chart XXI) follows the same general type of growth curve as the other parts of the digestive tract. There is no sex-difference.

The percentage weights of the liver forms a curve also resembling the percentage curves for the other parts of the digestive system, although the changes are not so marked. There is a short period of initial rise from 3.1 per cent at hatching to 6.2 per cent, followed by a slow decline to about 2.5 per cent. There seems to be a tendency for the liver in the females to run higher, possibly one per cent higher, than in the males. This is reversed for the six older chickens, for in these the percentage weights of livers in the males average higher than in the females. After the chickens become mature, they become very fat, especially the females. In some of these older fat chickens the liver had a yellowish color and these are the heavier specimens in chart XXI. For example, the last three cases (not included in the curve) were adults which were very fat and had the yellowish-colored livers. The female at 1640 grams had a yellow liver, also the females at 1520 and 1550 grams. The male at 1600 and the female at 1840 grams also have heavy livers but these livers were not specifically observed to be yellowish in color. They may have been, however, and no mention of the fact made on the record cards. The storage of additional glycogen, etc., in these livers is a possible explanation for the marked increase in the weight of the liver in the last three cases on the chart and for at least some of the heavier cases recorded for chickens under 2400 grams.

Welcker and Brandt ('03) give 1.88 per cent as the average percentage weight for the liver in two male fowls, which is lighter than that found in the present series. They record a variation from 1.68 to 4.74 per cent for various other species of birds. The liver of the chicken is lighter than that of the rat as given by Jackson ('13). He finds it forming 4.7 per cent at birth increasing to nearly 8 per cent at 3 weeks, later decreasing to about 4.5 per cent in the adult.

7. <u>Pancreas</u>.--Chart XXII shows the increase in weight of the pancreas plotted against gross body weight. This chart likewise resembles the other charts for the digestive system. Here also there is no marked difference in the curve when these weights are plotted against age, except for an initial flattening of the first part of the curve. There seems to be a good deal of variation in the distribution of the cases, especially toward the upper end of the curve. This may be due in part, although not entirely, to the greater difficulty in removing the pancreas free from all fat, mesenteries, etc.

In general, by way of summary, it may be said that the parts of the digestive tract do not show any marked differences in their growth rates (see charts XVII-XXII). The curve for the weight of the liver seems to differ slightly, increasing a little more slowly and uniformly throughout the entire range.

e. Respiratory System. Trachea and Lungs.

The lungs and trachea were removed and weighed together and their growth is shown in chart XXIII. Up to 1100 grams in gross body weight, the cases fall fairly well in line, but above this weight there is a great deal of variation. The same condition is seen when the weights are plotted against age. The cases are regularly arranged up to about 120 days, after which they are more irregular, especially in the males.

There is apparently a sex-difference in the respiratory tract in the chickens above 1200 grams in body weight, although but one curve has been made for both sexes in the accompanying chart. Donaldson ('15) shows no sex-difference for the lungs in the rat, and no sex-difference is found in the human species. It hardly seems probable that the crowing of the cockerel would make this difference, but this seems to be the only explanation for this apparent sex-difference.

f. Circulatory System. Heart.

The weights of the heart plotted against gross body weight are shown in chart XXIV. Here also, as in the case of the lungs, there is an apparent tendency to a sex-difference toward the end of the curve. It is, however, not so evident for the heart as for the lungs. This chart shows that the heart increases a little more slowly during the first and middle portions of the curve but continues to increase in the heavier chickens. After 1600 grams in gross body weight, the increase in the heart weight is marked, while in the digestive system, for example, there is practically no increase after a body weight of 1600 grams is reached. This is in accord with the condition found in the human, namely, that the heart increases slowly in weight after maturity.

The percentage weights of the heart show a very brief period of increase from 0.51 per cent at hatching to a maximum of 1.0 per cent on the 4th day. Then follows a decrease, rather rapid at first and then more slowly until the average percentage value is about 0.45 per cent for the females and a little less than 0.60 per cent for the males. This sex-difference is not apparent in the smaller chickens.

There is no apparent explanation for the relatively heavier heart in the cockerel any more than there is for the lungs. Possibly it may be associated with the increased activity of the cockerels, for as Joseph ('08) has suggested, the activity of an animal is correlated with the size of the heart.

Jackson ('13) found that in the rat the heart forms 0.65 per cent at birth, with a slight postnatal increase, gradually decreasing to about 0.40 per cent in the adult.

g. Ductless Glands.

1. Thyroid Gland.--The thyroid gland in the chicken is a rather small, oval gland located on each side at the base of the neck, or at the bifurcation of the common carotid artery. It consists of a single lobe on each side. Chart XXV shows the absolute weights of the gland plotted against gross body weight. In the smaller chicks it shows a much slower growth than do most of the organs, except the sex glands and the secondary sexual structures, such as the comb and ~~f~~ wattles. The female at 1290 grams in body weight had an unusually heavy thyroid, 0.417 grams. This weight was not averaged in the series, being excluded as either an abnormality or an error in the weighing. All three of the older cockerels had much heavier thyroids. These and the thyroid glands from the three hens were also excluded in the averages for the curve, although the individual cases are shown on the chart. There is apparently a sex-difference in the weight of

the thyroid in the six older chickens, but this may be due to a difference in diet. The three hens were taken from one of the pens of the regular laying stock, but the cockerels were from a lot of male birds kept by themselves all winter and from which breeding cockerels had been selected. The larger birds, both male and female, from these pens were selected in order to extend the upper end of the curve based on gross body weight.

The percentage weight of the thyroid is very constant, averaging 0.01 per cent throughout the entire series, although there are some irregularities. If there is a low part of the curve of the percentage weights when plotted on age, it comes between the 40th and 60th day (200-400 grams gross body weight) when the relative weight is depressed to about 0.0075 per cent. Later on it averages very slightly above 0.01 per cent. These variations do not seem to be significant. On the whole the thyroid seems to maintain its relative weight to a surprising degree.

2. Thymus.--The thymus of the chicken is located farther cephalad than the thyroid. It consists of a chain of lobes lying along each side of the neck, from the larynx down to the thyroid gland. The larger lobes, which persist longer when the gland begins to atrophy, are as a rule located at the base of the neck or nearer the thorax. The lobes are usually of a pinkish color, although some were much darker.

Chart XXVI gives the thymus weight plotted against age in days. The weights of the thymus plotted on gross body weight do not give nearly so regular a curve as that shown in chart XXVI, according to age. The first or growth phase in each of the two curves is very similar, but the position of the older pullets (toward the center of the chart based on body weight) produces an irregular and more abrupt second or involution phase of the curve. Evidently the thymus involution in the chick depends on age rather than body weight, as was found by Hatai ('13) for the rat.

The thymus of the chicken follows the usual course of development for the gland as found in other animals. It increases slightly more rapidly than the body weight up to 130 days, and then it decreases to nearly the same absolute weight as that of a chick 40-50 days old. The relative weights in the older chickens are naturally much less. At first the thymus forms a little less than 0.3 per cent of the net body weight. This percentage rises until at from 110-130 days it forms about 0.5 per cent; then there is a decrease until it reaches about 0.05 per cent for the older chickens of my series, and slightly less, or nearer 0.025 per cent, for the adult chickens.

The gross appearance of the involution changes indicate that the usual two methods of obliteration are found in the chicken, namely, a fatty or a fibrous involution. The lobes become smaller and later a decrease in the number of lobes is apparent. Throughout the entire period more or less fat was found surrounding the thymus and the lobes were enclosed by the fascia.

Jackson ('13) found the following relative weights for the thymus in the male white rat; at birth it forms 0.15 per cent, which makes it slightly heavier than that of the chick, then it increases to a maximum of 0.38 per cent at 20 days, and again decreases to 0.02 per cent at one year. The rat matures more rapidly than the chicken, so this earlier maximum in the growth of the thymus is to be expected.

3. <u>Spleen</u>.—Chart XXVII, which gives the weight of the spleen plotted against gross body weight, shows that the spleen is extremely variable in the chicken, as it has been found in other animals. There is no sex-difference.

4. Suprarenal Glands.--Chart XXVIII shows the growth of the suprarenal glands plotted against gross body weight. Some of the irregularity in the upper part of this curve may be due to the difficulty in removing these glands. In the female the left suprarenal is lodged at the base of the ovarian ligament, and when the ovary is fully developed the ligament is strong and tough and the removal of the left suprarenal gland, without injurying it, is difficult.

There is possibly a very slight increase in the percentage weights of the suprarenal after hatching, with a maximum value of 0.0359 per cent on the 4th day. Then there is a decrease until the average for the adult is about.01 per cent. These values are slightly greater for the maximum and a little less for the adult than given by Jackson ('13) for the male rat. The suprarenals are considerably larger in the female rat. Unlike the rat, there is no sex-difference apparent in the chicken.

5. Hypophysis.--The hypophysis of the chicken seems to be quite variable in weight as shown in chart XXIX. A similar irregularity in the arrangement of the cases is observed when age rather than gross body weight is used for the abscissa. The percentage weights are also extremely variable at first (due possibly to the difficulty in removal). After this first irregular period with an average of about 0.068 per cent of the net body weight, there is a rather precipitous fall in the percentage weights to about 0.0015 per cent followed by a slow decrease to about 0.0006 per cent, which is also the average percentage weight for the three older cockerels. The hypophysis of the three hens average about 0.0005 per cent.

In the rat there is a marked sex-difference in the weight of the hypophysis, the female being the heavier (Hatai '13; Donaldson '15). The data on the chick shows no appreciable sex-difference when the weights are plotted against body weight. If there is any difference at all it is rather in favor of a heavier male hypophysis.

h. Urogenital System.

1. Kidneys.--The growth of the kidneys plotted against gross body weight (chart XXX) shows a marked initial rise followed by a gradual decrease in rate of growth. There is no significant sex-difference and no peculiarities in the weight of the kidneys in the older cockerels and pullets.

The percentage weights show a marked initial rise followed by the usual decrease, and a terminal irregular portion. At hatching the kidneys form 0.6 per cent of the body weight, but they rise rapidly until at five days they form 2.0 per cent, which is the highest case of the entire series. The average for the older birds would be about 0.7 per cent, with the adult cases a little less. The older pullets seem to have slightly heavier kidneys, relative to body weight, than do the cockerels of the same age.

Welcker and Brandt ('03) give 0.59 per cent for the kidneys in two adult male chickens which is about the same as the average percentage values for my three older cockerels. Jackson ('13) gives the following percentage weights for the kidneys of the male rat: at birth, 0.96 per cent; at seven days, 1.29 per cent; and a maximum of 1.44 per cent at twenty days; it then decreases to 0.95 per cent at one year.

2. Ovary and oviduct.--Chart XXXI shows the increase in weight of the ovary (large dot) and oviduct (dot and circle) plotted against age. The distribution of cases is very irregular but less so than when plotted against body weight. No attempt has been made to draw a curve for these organs, since both are very irregular in their growth

and the number of cases is not sufficient to justify a curve. The weights are for the empty oviduct. One egg (never more) was sometimes found in the oviduct, but it was removed before weighing the egg-tube.

Four phases of ovarian growths are recognized: (1) an initial period of very slow growth, followed by (2) a slight increase in growth rate; then (3) a period of very slow growth followed by (4) a second period of more rapid growth. This is a brief prepubertal period of rapid growth which lasts but about 30 days, or from about 160 to 190 days of age.

The oviduct was not weighed in the smaller chicks, but from about 80 days up to 160 days of age it was always a little lighter than the ovary. In the pullet at 162 days the positions were reversed, the oviduct becoming heavier. The oviduct continues to be the heavier, with two individual exceptions: the pullet at 286 days and one of the two year old hens.

The pullet at 188 days had a fully developed egg in the lower end of the oviduct and the following day an egg was laid by one of the other pullets of this group (group I). Between the pullet at 181 days and that at 188 days, in an interval of seven days, the oviduct shows an increase from 8.66 grams to 82.75 grams or about 8.6 times, while the ovary has increased from 2.108 grams to 38.94 grams or 17.5 times. In addition the ovary and oviduct have produced the egg which was found in the oviduct of the pullet at 188 days.

The relative weights of ovary and oviduct undergo a correspondingly large increase. The oviduct increases from 0.69 per cent to 5.62 per cent, or 7.1 times; and the ovary increases from 0.17 per cent to 2.65 per cent, or 14.5 times. No eggs were found in the pullets at 230 and 243 days. The pullet at 243 days is from group III, the other pullets above 188 days are all from group I.

In the pullet at 230 days there was an interesting example of what appeared to be an ovum which was being resorbed. The yolk-mass had apparently been partly resorbed until the membrane was not tense (as it usually is), but flabby. A similar condition was seen in two of the hens.

It is interesting to note that the ovary and oviduct are closely correlated in weight, both increasing or decreasing proportionally.

The greater weight of the ovary in the pullet at 286 days and in one of the hens may be due to the presence of a fully mature ovum, just ready to emerge from the ovary.

The increase in the diameters of the ovarian ova was also recorded, and it apparently is a more gradual change than is indicated in the change in weight as shown in chart XXXI; for the diameter of the largest ovum (only the largest was measured) increases slowly while at the same time there is almost no increase in the weight of the ovary from the 100th to the 155th days.

In every female but one (the 3 day chick) only the left ovary was found, and no trace of the right ovary was seen. As stated above, the suprarenal on the left side is more and more enveloped by the ovarian ligament as the ovary increases in size, but on the right side the suprarenal is covered by only a thin capsule of connective tissue. In the three day chick there was a small mass of tissue (not weighed) ventral to the right suprarenal which looked as though it might be a degenerating ovary. Unfortunately it was not preserved for histological study.

3. <u>Testes</u>.--The growth in weight of the testes (without epididymis) plotted against gross body weight is shown in chart XXXII. Here also no attempt has been made to draw a curve, for the cases are too few in number and too irregularly distributed. There are,

however, definite indications of the four phase curve found in the growth of the mammalian testes. There is (1) a period of slow growth up to 400 grams in body weight (or about 50 days); then (2) an increase in growth from 400 to 700 or 800 grams in body weight (50-80 days); and then (3) a period of rapid or pubertal growth from 1800 to 1950 grams in body weight (210-260 days); and (4) a terminal plateau or period following sexual maturity. This last period is not well shown in the accompanying chart.

i. Nervous System and Sense Organs.

1. Brain.--The same precocious growth which characterizes the development of the brain, spinal cord and eyeballs in mammals is found in the chick. Chart XXXIII shows the growth of the brain, plotted against gross body weight. The rate of growth is very rapid at first and gradually decreases as the body weight increases. There is no significant sex-difference, although there is, as in other organs, an apparent difference when the brain weight is plotted against age (due to the sex-difference in groww body weight in the later periods).

The percentage weights of the brain show no initial rise but a decrease from about 2.5 per cent at time of hatching. The decrease is rapid at first, or until it reaches about 0.5 per cent, and then a very slow decrease until it reaches about 0.2 per cent, which continues as the percentage weight for the brain of the adult chicken. Welcker and Brandt find that the brain forms 0.24 per cent of the body weight in the two male chickens. This is but slightly heavier than the relative brain weight for the older males of my series.

Jackson ('13) states that in the rat the maximum relative weight of the brain is attained at seven days, after which it decreases. The curve of brain weights in the rat, plotted against body weight, as shown by Donaldson ('15) is very similar to that of the chick as shown in my chart XXXIII.

2. Spinal Cord.--Chart XXXIV shows the growth of the cord, plotted against gross body weight. It does not show the rapid growth during the smaller body weights to as marked a degree as does the curve of brain growth. There is in this case an apparent sex-difference (of doubtful significance) at the upper end of the curve.

The relative weights of the spinal cord show no initial increase (as found in the rat). At time of hatching the cord forms 0.5 per cent of the body weight. This decreases rapidly at first, then more slowly until it reaches about 0.14 per cent.

Welcker and Brandt ('03) give 0.13 per cent for the relative weight of the spinal cord in two adult male chickens. Both the brain and the cord are relatively heavier in the rat than in the chicken.

3. Eyeballs.--Chart XXXV shows that the growth in weight of the eyeballs is essentially similar to that of the brain and spinal cord. This curve, however, indicates a greater variability than is found in weights of brain and spinal cord. There is the same indication of a sex-difference (of doubtful significance).

Welcker and Brandt ('03) found a relative weight of 0.30 per cent for the eyeballs in the chicken, which is a little higher than found in my series. My three older cockerels averaged 0.22 per cent and the hens 0.21 per cent. The maximum relative weight of the eyeballs in the chick comes at time of hatching, with a rather strikingly larger percentage weight for the males during the first few days.

VI. Discussion.

The growth of the body as a whole in the chicken seems to be different from that described in man by Scammon ('20). The general character of the curve of growth in my series is similar to that of the preceding investigations on the chicken. This curve shows three phases: (1) a period of slow growth, which includes a brief period of postnatal decrease; then (2) a period of rapid growth, followed by (3) another period of slow growth. This general type of curve holds in the chicken not only for the growth of the entire body but also for the muscles, ligamentous skeleton, digestive tract, lungs, heart, kidneys, suprarenals and integument, when their weights are plotted against age. In man, the growth curve of the body as a whole and all of the above parts, excepting the suprarenals, is a four-phase curve. The suprarenal in man (according to Scammon) shows 'a great decrease in weight in the neonatal period, an interval from the neonatal period which extends through the greater part of childhood when there is little growth, and a period of rather rapid growth in the prepubertial period and in adolescence'.

There is in the chick but slight indication of a slowing of growth, corresponding to the decreased rate of human growth in middle childhood. It is very doubtful whether anything corresponding to the characteristic human prepubertial acceleration of growth occurs in the body as a whole of the chick.

When the weights of the organs and systems are plotted against gross body weight instead of age, the first period of slow growth is usually not observed, as shown in the various charts. The exceptions to this are the curve for the thyroid, which is distinctly concave upward throughout its entire length; also those for the muscles and integument, which are nearly straight, and those for heart and lungs.

Another type of curve described by Scammon ('20) for the growth in the weights of the human brain, spinal cord and eyeballs is similar to the curves for the same organs in the chick, when the weights are plotted either on age or on gross body weight. All of these curves rise rapidly at first and then more slowly flatten out.

The type for the human thymus with an initial rise up to the age of puberty followed by a decrease in weight is, according to Hammar, characteristic for mammals in general. The present study shows that it holds likewise for the chick. It is also the type of curve found for the growth of the feathers, a fact apparently hitherto overlooked. As above explained, however, the decrease in the weight of the feathers is due to a process quite different from the involution of the thymus.

The growth of the testes of the chicken shows (1) an initial period of but little change; (2) a slightly increased rate of growth followed by (3) a second period of slow growth, (and of marked irregularity), then a period of very rapid prepubertal growth and finally (4) a period of slow growth. The cases are too few to make a smooth curve but they indicate the above four phases. This is similar to the curve of growth for the human genital organs, excepting ovary and uterus.

The ovary and oviduct of the chicken seem to grow slowly until the very rapid prepubertal growth, after which there is a period of but little growth. The oviduct is lighter than the ovary up to the prepubertal rise. The number of cases is insufficient to warrant final conclusions concerning the growth of the ovary and oviduct, and a comparison of their growth with that in other forms is therefore omitted.

Sex-differences.--The curves of the growth of the body as a whole show a sex-difference apparent very soon after the beginning of the second or rapid pubertal growth phase of the curve. This means that at any age after 8 weeks the male chickens average heavier than the females of equal age.

The linear measurements of the body also show a marked slowing of growth in the female earlier than in the male. This means that the female skeleton ceases to increase in length earlier than does the male skeleton. A similar difference in extent of growth is true for other organs, but this does not necessarily mean that these organs are proportionally heavier in the male of the same body weight. Plotting these organs against gross body weight usually shows clearly that they are relatively of about the same weight in male and female. As has been mentioned, there still persists a definite sex-difference in the weights of the head, skeleton, and feathers and a less marked sex-difference in the heart and lungs. The digestive system and all of its parts (except the liver), and the nervous system and eyeballs show a slight sex-difference in the upper parts of the growth curves for these organs. By the time this sex-difference becomes apparent, the chickens are sexually mature and the females are all fatter than the males. The extra fat thus increases the total body weight perhaps enough to account for the apparent lowering of the weights of the organs in the females, when plotted against body weight. The liver does not follow the same plan as the other parts of the digestive tract, for it also apparently becomes loaded with the surplus food material and the fat females therefore also have heavier livers. This is readily seen by reference to chart XXI.

If, however, the surplus fat in the females makes the digestive system and the nervous system appear relatively lighter in the females, it should affect <u>all</u> of the organs similarly. But the suprarenals, thymus, spleen, skin and kidneys do not show this effect. It is true that most of these curves are more irregular, but at least some indication of the sex-difference in weight might be expected, unless some other factor is concerned in this group of organs.

The poultrymen say that the chickens two years old should be heavier than at one year of age. Although my cases are very few, it may be interesting to see what changes are apparent in the structure of the older chickens. There appears an actual increase in the weights of the kidneys of two of the three hens. The heart shows an increase in absolute and in percentage weight. The thyroid becomes extremely variable, heavier for one and much lighter in two of the females. The amount of fat was not determined accurately, but from inspection it is apparent that a very large part of the change occurring in the second year is due to the increase in the amount of fat. There is an absolute increase in weight of the muscles (possibly due to more fat within them), though they still maintain the same relative (percentage) weight.

VII. Summary.

The more important findings may be summarized as follows:

1. The curve of postnatal growth of the entire body of the chicken shows three general phases: first, a period of slow growth, including a brief postnatal decrease in weight; second, a period of rapid (pubertal) growth, during which a sex-difference in body weight begins; and third, a period of slow increase in weight.

2. The weight of the head shows a marked sex-difference due apparently to the larger development of the comb and wattles in the male.

3. The growth in weight of the skin (excluding feathers) is directly proportional to that of the entire body, forming about 8 per cent of the net body weight in the adult.

The feathers increase in both absolute and relative weights up to just before sexual maturity. Then follows a decrease in absolute and relative weights, the growth curve thus resembling that of the thymus.

4. The muscles increase from 21 or 22 per cent at hatching to about 50 per cent of the body weight in the adult.

5. The skeleton at first grows a little less rapidly than the entire body. It forms 11 per cent of the body weight in the mature male, and 9 per cent in the female. The weights and linear measurements show that the female skeleton matures earlier than the male.

6. The digestive tube and its regions, stomach, gizzard and intestines, and also the pancreas, all grow at about the same rate, showing a short initial rise in relative weight, followed by a slow decrease up to maturity. The empty tube reaches a maximum of 18.5 per cent of the body on the 6th day, decreasing to about 5 per cent in the adult.

The weight of the 'tare' (contents of the digestive tube) is extremely variable.

The yolk-sac was found in all chickens autopsied, with one exception, up to and including the 38th day; and thereafter frequently up to the 237th day. Meckel's diverticulum is constantly present.

7. The liver decreases from an early maximum of 6.2 per cent of the body weight to about 2.5 per cent in the adult. Its weight increases markedly in the older chickens, especially in the fat females.

8. The weight of the trachea and lungs is variable and shows an apparent sex-difference in the older chickens, being heavier in the males.

9. The heart also shows a sex-difference in the older chickens forming about 0.45 per cent of the body weight in the female and 0.60 per cent in the male. It rapidly doubles its initial relative weight, reaching 1.0 per cent on the fourth day, and decreasing gradually thereafter.

10. The relative weight of the thyroid gland appears usually constant from day of hatching to about two years of age, averaging about 0.01 per cent of the net body weight.

11. The thymus increases in both its percentage and absolute weight up to sexual maturity and then undergoes involution, decreasing in relative and absolute weight. Its changes are more closely related to age than to body weight.

12. The suprarenals and hypophysis are somewhat variable in weight but neither shows a sex-difference.

13. The kidneys show a marked initial rise from 0.6 per cent to 2.0 per cent of the body weight at five days, followed by a slow decrease to about 0.7 per cent in older and adult chickens.

14. The ovary, oviduct, testes and comb and wattles, are all extremely variable in weight. They all tend to form a four-phase curve of growth, with a marked acceleration at puberty.

15. The brain, spinal cord and eyeballs increase rapidly at first, followed by a slow growth later. The relative (percentage) weights of these organs show no initial rise, but decrease progressively from time of hatching.

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IX. Explanation of Charts.

Key to Plates.

Solid dot - weight or measurement of the males (except in Chart XXXI where it represents the weight of the ovary).

Circle - Weight or measurement of the females.

Adult - Adult chickens (the three older cockerels and the three two year old hens).

Abscissae in all charts are either gross body weight in grams or age in days.

Chart I. This chart shows the average weight per chicken for group I, plotted on age in days. The sexes were weighed separately after the sixty-second day, and separate weights were plotted for the males and the females. The males are increasingly heavier after this date.

Chart II. This chart shows the average weight per chicken for group II, plotted on age in days. Both sexes were weighed together.

Chart III. This chart shows the average weight per chicken for group III, plotted on age in days. The males and females were not weighed separately until the seventy-ninth day. From this time on the males are distinctly heavier.

Chart IV. This chart shows the average weight per chicken for group IV, plotted on age in days. The males and females were weighted together. Comparison with the three preceding charts will show a slower rate of growth in this group.

Chart V. The two lines in this chart show the average weight per chicken for each week, for all groups. Up to the fifty-sixth day the line represents the average for both sexes; after this time the upper line represents the average for the males and the lower line that for the females.

The dots and circles represent the gross weights of the autopsied chickens.

Chart VI. This chart shows the average weight in pounds of all chicks for the first twenty-five days. This curve is plotted on a larger scale to show the postnatal decrease in body weight,(days 0-4).

Chart VII. This chart shows the nose-anus length,or the length from the tip of the bill to the cloacal opening,measured in centimeters,and plotted on age in days.

Chart VIII. This shows the length of the leg measured from the greater trochanter of the femur to the tip of the extended toe(middle toe), in the upper row (with a sex-difference at the upper end of the row). The length of the wing measured from the greater tuberosity of the humerus to the tip of the extended wing is shown in the lower part of the chart. Both measurements are in centimeters. The sex-difference is not so apparent in the wing measurements.

Chart IX. This chart shows the dorso-ventral diameter (upper) and the transverse diameter(lower) of the thora x,plotted on age in days. Both diameters are in centimeters and and were made just posterior to the anterior end of the crest of the sternum.

Chart X. This chart shows the length of the head in centimeters, measured from the tip of the bill to the most posterior part of the head. These measurements are plotted on age in days.

Chart XI. This chart shows the growth in weight of the entire head, without feathers,plotted on gross body weight. The line represents the average of the individual cases,which are shown by dots or circles according to sex. The cases at 2300 and 2440 grams gross body weight were too h heavy to be included on the chart. Their weights were,respectively,113 and 131 grams. The cases above a gross body weight of 2200 grams are shown on the chart but they are not included in the averages for the curve. A marked sex-difference is apparent after 300 grams gross body weight.

Chart XII. This chart shows the weight of the integument (without feathers) plotted on gross body weight. The line represents the average of the cases, which are indicated by dots for the males and circles for the females.

Chart XIII. The weight of the feathers is shown in this chart, plotted on the gross body weight. The weight of the feathers of the pullet at a gross body weight of 1210 grams and all of those above 2200 grams gross body weight are shown on the chart but they are not included in the averages for the curves.

Chart XIV. This chart shows the weight of the comb and wattles plotted on gross body weight. The ear lobes are shown for the older chickens only. The dot and circle represent the ear lobes of the male and the double circle, the weight of the ear lobes of the females. No attempt has been made to draw a curve for this chart for the cases are too irregular.

Chart XV. This chart shows the weight of the muscles plotted on gross body weight.

Chart XVI. The weight of the moist ligamentous skeleton plotted on gross body weight, is shown in this chart. The male skeletons are heavier aftera gross body weight of about 900 grams is reached.

Chart XVII. THis chart shows the weight of the digestive tube (without contents), plotted on gross body weight.

Chart XVIII. This chart shows the weight of the stomach(without contents) plotted on gross body weight.

Chart XIX. The weight of the gizzard(without contents) is shown in this chart. The weights are plotted on gross body weight.

Chart XX. This chart shows the weight of the esophagus, crop and intestines (all without contents) plotted on the gross body weight. As in the preceding charts the line represents the average of the cases whddh are shown by the dots and circles.

Chart XXI. Thés chart shows the weight of the liver plotted on gross body weight. The three cases above 2400 grams gross body weight are shown on the chart but are not included in the averages for the curves.

Chart XXII. This chart shows the average weight of the pancreas as a line and the individual cases as dots and circles,plotted on the gross body weight.

Chart XXIII. This chart shows the weight of the trachea and lungs plotted on the gross body weight. The average growth is shown by the line and the cases by the dots and circles.

Chart XXIV. This chart shows the weight of the heart plotted on gross body weight.

Chart XXV. This chart shows the weight of the thyroid gland plotted on gross body weight. All the cases above 2200 grams gross body weight, or the adults,and the pullet at 1290 grams, and the hen at 1920 grams, gross body weight are shown on the chart but are not included in the averages for the curves.

Chart XXVI. This chart shows the weight of the thymus plotted on age in days.

Chart XXVII. This chart shows the weight of the spleen plotted on the gross body weight.

Chart XXVIII. This chart shows the weight of the suprarenals plotted on gross body weight.

ChartXXIX. This shows the weight of the hypophysis plotted on the gross body weight.

Chart XXX. This chart shows the weight of the kidneys plotted on gross body weight.

Chart XXXI. This chart shows the weightsof the ovaries and the oviducts plotted on age in days. The weights of the ovaries are represented as solid dots and the oviducts,as circles. Both the ovary and the oviduct of one of the hens were too heavy to represent on the chart. The weights were, 68.5 grams for the ovary and 50.7 grams for the oviduct.

Chart XXXII. In this chart the weight of the testis, in grams, is shown as solid dots. The weights are plotted on the gross body weight. The five cases in which the weight of the testes exceeds twenty grams, are shown at the upper margin of the chart and the proper weights are indicated.

Chart XXXIII. This chart shows the weight of the brain plotted on gross body weight.

Chart XXXIV. This shows the weight of the spinal cord plotted on gross body weight.

Chart XXXV. This chart shows the weight of the eyeballs plotted on gross body weight.